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THE BARRIERS TO IMPROVING INFORMATION MANAGEMENT IN ENGINEERING ORGANIZATIONS: A STUDY OF SMALL TO MEDIUM-SIZED ENTERPRISES

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ABSTRACT

The use of information and the development of more effective strategies for its management is one of the most important issues facing today's knowledge dependent engineering organisations. For these reasons, considerable work has been undertaken to understand and improve information management within larger organisations. However, where small to medium-sized organisations are considered little empirical work has been undertaken. To address this, a detailed study of the issues concerning information management across ten engineering SMEs from the Advanced Engineering sector has been completed.

This paper presents an overview of the study and includes a discussion of the research method and in particular, the important tasks of data collection and data filtering. Following this, the processes of characterising the generic issues and the assessment of causality and dependency between the issues are described. Using the empirical data, a set of fundamental issues is proposed which may be considered to represent the key barriers to improving information management within engineering SMEs. These barriers and their implications are then discussed and a number of important considerations are highlighted. It is also clear that the findings of this study and the understanding gained are not only critical for improving information management but also for the development and planning of an effective information systems strategy within this class of organisation.

Keywords: Information management, information systems strategy, information flow, engineering SMEs

1 INTRODUCTION

The use of information and the development of more effective strategies for its management are amongst some of the most important issues facing today's knowledge dependent organisations. Information and knowledge held in a variety of sources are essential for strategic planning, management, control, tactical planning and daily operation [1, 2]. In fact, for many organisations, information is a prerequisite for the production and delivery of existing and new products and services. For these reasons, information management is widely accepted as being one of the key mechanisms by which innovation, organisational performance and operating efficiency can be improved [3-6].

In order to improve information management within the modern computer-driven organisation there are two important dimensions, namely information and the information systems. The information system dimension involves a range of technical, systems and behavioural considerations which need to be addressed by an organisation in order to successfully develop their information systems infrastructure. In addition to these dimensions the importance of effectively specifying, implementing and managing a collection of information systems to support the organisation as a whole is recognised by a number of authors [7, 8]. For example, Duhan et al [9] conclude that "It is the use and management of information systems that confer advantage not their mere existence". This therefore leads to another important factor for information management, the overall management of the

infrastructure. It is this overarching dimension which is becoming increasingly important as employees, customers and suppliers all require accurate and up-to-date information from a wide variety of sources and different systems from across the entire organisation and the supply chain.

As has been previously stated, information management is critical to the operation and ultimately the long-term commercial success of any organisation. However, it is of particular importance for engineering organisations where both a substantial amount and wide variety of information is necessary to support design, manufacture and a product over its lifetime [10, 11]. For example, within engineering organisations information may reside in, or be represented by, analysis models, CAD files, correspondence, documents, emails, lead time, manufacturing schedules, meeting records, procurement information, service reports and suppliers literature. Much of this information is highly structured and held in formal information systems, such as product data management (PDM) systems and customer relations management (CRM) systems, a variety of less formal information may also reside in user-developed systems, such as spreadsheets and reports. For the reasons previously discussed all these systems need to be managed in order to realise an integrated and effective information management infrastructure.

Because of this reliance on information considerable work has been undertaken to improve overall information management within engineering organisations. This includes Document Management Systems (DMS) and Enterprise Resource Planning (ERP) systems. However, many of the solutions require major levels of investment and / or business process redesign. As a consequence, many small to medium-sized organisations are reluctant, or unable, to implement the systems, preferring to acquire systems and tools on an 'as needed' basis. However, this approach and lack of formal strategy can result in new elements which may only replace a current problem with a new less well understood problem. Furthermore, because systems are built on top of one another it can be difficult to determine the life-cycle of a particular information system [12] and it is unlikely that elements are well integrated or well managed. It therefore follows that in order in order to improve information management in engineering SMEs there is a fundamental need to firstly understand the information issues they face, and establish the fundamental barriers to improving information management. To address this, an empirical study of small to medium-sized engineering organisations is undertaken and the results analysed in detail to establish what can be thought of as the barriers to improving information management.

2 RESEARCH METHOD

In order to establish the issues concerning information management faced by small to medium-sized engineering organisations, empirical data was collected through semi-structured interviews. A semi-structured approach was adopted so that all the various facets of information management could be considered rather than dealing with specific technologies, particular hardware or software systems. Furthermore, this broader approach helped to reduce interviewer bias and allow the participants to direct discussions and describe the issues which their organisation is, or has recently experienced. The interviews included director(s), representatives from technical departments, IT departments and finance. In the majority of cases the participants were interviewed collectively at their organisation to enable a more general consensus to be agreed between the participants. As a result of this, the data is considered to provide a more unified and reliable perspective of today's small to medium-sized organisation.

2.1 Participants

In total, ten engineering SMEs were investigated over the 2004-2005 financial year. The organisations participating in the study had workforces of up to 250 employees and / or a turnover of less than £28 million. All organisations were UK based and located in the South of the country. The turnover and workforce of each organisation is shown in figure 1.

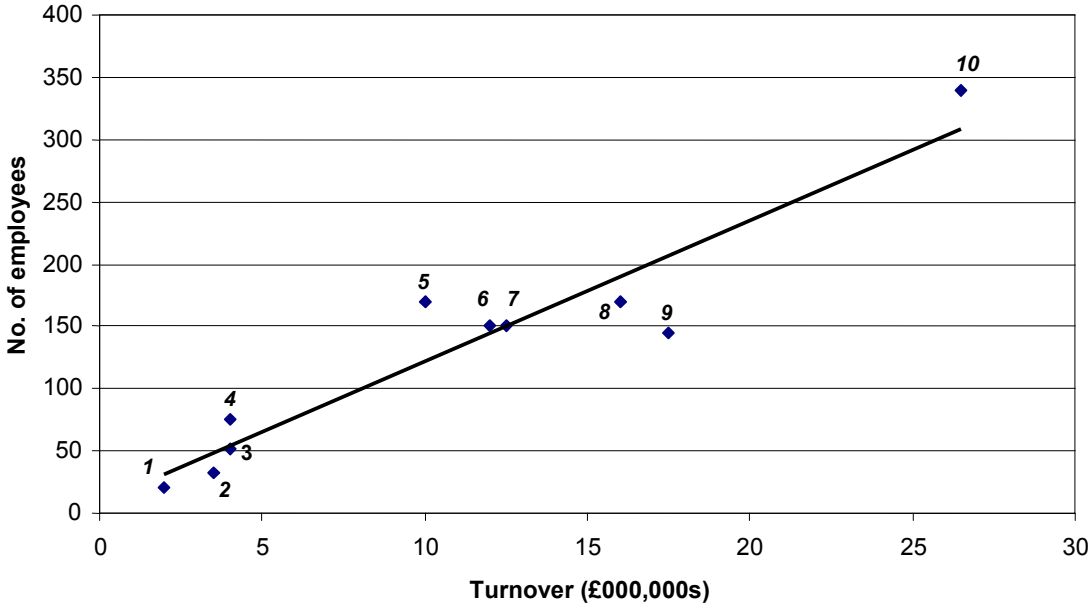

Figure 1. Organisational profile of participants

2.2 Data collection and processing

A consequence of the semi-structured interview approach is that a large amount of data was collected which represented issues that were beyond the scope of this study. In order to remove these, the data from each interview was filtered and then pruned. The filtering and pruning procedures are important elements in the overall analysis and ensure that the issues dealt with in the subsequent analysis share a common focus and can ultimately be used to inform a generalised and representative perspective of the industry sector considered.

2.2.1 Filtering

The first stage of processing was applied to remove those issues which were deemed to be outside the scope of this study. This involved removing issues that did not relate to aspects of information management or the business and operational processes of engineering organisations; including design, manufacture and the product lifecycle. This filtering process eliminated more than twenty issues reducing the total number of cited (specific) issues to 180. In this work the terms cited and specific are used interchangeably to denote the issues identified by the organisations.

2.2.2 Pruning

The second stage of processing was undertaken to separate issues relating to information management and those relating to other business and operational aspects of engineering SMEs. This was achieved by referring to the three dimensions of information management (information, information systems and overall management) highlighted previously. This resulted in the removal of 71 issues leaving a total of 109 cited issues. Of the 109 issues there was a good spread across the 10 organisations with each contributing an average of 11 issues, with a minimum of 7 issues.

3 A CLASSIFICATION OF INFORMATION MANAGEMENT ISSUES

A preliminary assessment of the 109 issues purported that the specific issues represent a variety of more generic issues. In order to explore this further, the specific issues were used to characterise and develop a classification of what may be considered to be the generic issues. This classification process established 18 generic issues which are defined in detail in Table 1. In addition to defining each issue a number of specific examples are included in order to provide the reader with an insight into what the participants were concerned about.

	Issue	*Detailed description of generic issue*	*Summary*
1	**Information exchange**	This issue relates to the inability or difficulties of exchange of information between different computer based systems. These include Product Data Management (PDM) and Materials Resource Planning (MRP), MRP and Computer Aided Design (CAD), MRP and Customer Relationship Management (CRM), and the PDM and product configurator. In addition to these process and software limitations, difficulties concerning information exchange were also identified where different standards were adopted. This includes the exchange of CAD/CAM data between different sites and also with customers, and where different part numbering conventions were used for Computer Numerically Controlled (CNC) systems and CAD components. Furthermore, in two cases different internal numbering systems for part codes were used by purchasing and the design department respectively.	• Inability to exchange information between: 1. MRP and PDM 2. MRP and CAD 3. MRP and CRM 4. PDM and product configurator • Use of different standards 1. By organisations 2. Over different sites 3. By departments – part codes
2	**Manual systems and data entry**	Half of the cited issues in this class can be attributed to the inability to automatically exchange information between different systems. Reasons for this include hardware and software issues and also implementation issues. In contrast to this, in some cases data is manually entered to overcome limitations of a new system. For example, one organisation maintained a legacy system to enter data purely because the user can 'tab' across entries rather than 'mouse clicks'. The latter of which is far more time consuming when entering large amounts of numerical data. In addition to this, one organisation implements a manual procedure for data transfer between the design office and the MRP system, and use this as an important element of their quality control system.	• Due to inability to exchange data • Overcome limitations of another systems – data input speed • Manual timesheets • Manual works orders
3	**Monitoring, control and costing**	This class of issue was cited by over half the organisations and concerns the inability to accurately cost projects for quotation purposes, undertake variance analysis for completed projects, and the inability to monitor time, work in progress and processes on the shop floor. The latter of which has a significant impact on the ability to effectively schedule manufacturing operations and evaluate current capacity and capabilities.	• Generate accurate quotations • Monitor time, WIP & shop floor processes • Variance analysis
4	**Customer and sales Information**	Issues relating to the supply of customer and sales related information concerns poor information flow and in particular the information supplied to the organisation by sales representatives. One organisation also identified that their sales process was not well formalised. Furthermore, the lack of information relating to current capabilities and product range was also cited as one reason which frequently contributed to the sales team not being well informed. To overcome this, one organisation was considering partnering sales with members of the engineering team to overcome some of the information flow issues.	• Poor information provided by sales • Lack of formalised sales process
5	**Information systems functionality**	This concerns the failure of computer based systems to deliver the required functionality. Most cited issues concern the inability of an MRP system to manage costing and contact data and the failure of the PDM systems to handle drawing files created within different CAD systems. This latter aspect is particularly common given the requirement for organisations to manage legacy 2D drawings for spares and support of existing customers. It also compounds issues concerning the numbering and traceability of machines, assemblies and components.	• Inability of MRP system to manage cost and contact data • Inability of PDM system to handle both 2D and 3D drawings files and files from different CAE systems
6	**Information storage**	Issues relating to the storage of information concern the cost of maintaining legacy information, and particular scanning and archiving. This includes hardware, software licences and the physical space. In addition to this, a number of organisations raised concerns over the increased amount of information that needs to be managed to conform to the ISO 9000/2 quality standard. One organisation maintains two archive rooms full of files for this purpose which are rarely accessed.	• Cost of keeping legacy data • Increased amount of information to manage as a result of ISO 9000/2
7	**End-user developed applications**	This class of issue relates to the widespread utilisation of end-user developed applications. These include spreadsheets, databases and linked documents which are used in addition to, or instead of, certain elements of the core information systems. In general, desktop or office applications were used to supplement the MRP system, PDM and Sales / CRM systems. Reasons for this are likely to be a combination of costly local customization of the core information systems and the high level of functionality and relatively small costs of the latest generation of office applications.	• Overcome limitations • Avoid customization • Supplement 1. MRP 2. PDM 3. Sales 4. CRM
8	**Information systems use and maintenance**	Issues relating to the use and maintenance of the information system fall into two categories; integration and training. Integration concerns the often extended timescales necessary to fully implement, commission and accept a new information system and in particular the MRP system. Training issues concern the cost to train one or more individuals. For these reasons, there are often only a few users capable of proficiently operating a given system and act as Gatekeepers. This can pose a significant problem when individuals are either unavailable or leave. Furthermore, the lack of resources for training may well contribute to the lengthy periods of time necessary for full implementation.	• Long timescales necessary to fully integrate MRP system • Cost of training • Wide spread use of 'Gatekeepers' – large knowledge gap if gatekeepers leave
9	**Numbering of machines, assemblies and parts**	Issues concerning the numbering of machine parts concerns two distinct areas. The first of these concerns best practice and associated strategies for part numbering that support the transition from legacy 2D drafting systems to 3D modelling environments. In particular, conventions need to be adopted which enable systems, assemblies and individual components to be managed within the 3D modelling environment, and also support the large number of legacy drawings and part codes associated with 2D drafting systems. The second area relates to the ability to track small design changes and add-ons frequently necessary during the commissioning and development activities undertaken by machinery manufacturers.	• Transition from 2D numbering systems to 3D • Tracing of design changes made during commissioning

Table 1. Definition of the 18 generic issues

	Issue	*Detailed description of generic issue*	*Summary*
10	**Information availability and accessibility**	This class of issue concerns the need to make information collected by technical departments and service engineers available to the entire organisation and in particular sales. The importance of this information to support and inform the new product introduction process was also recognised. In addition to this, the requirement for a centralised approach to the management of all electronic files and documents across the entire organisation was also observed by organisations. In fact, this organisation is currently implementing a programme to manage a large proportion of its documents and correspondence on a corporate Intranet. The organisation no longer and distribute the full content of a document to each employee rather a hyperlink to the referenced document on the Intranet is distributed by email.	• Make information from 1. Technical departments 2. Service engineers available to Sales • Need a centralised approach for the management of electronic files
11	**Information systems implementation and customization**	Issues concerning the information systems customization of core relate to the need for considerable local customization of the MRP system and may also be one of the reasons why end-user developed applications are now being more widely used. In fact three of the organisations that cited an issue relating to customization also highlighted the increasing use of end-user developed applications instead of elements of the core information system.	• Time and resources necessary to fully implement and align MRP system to organisation
12	**Information identification, location & organisation**	This class of issue concerns the ability to identify, locate and organise documents, correspondence and multiple workstations and user file space. Clearly the inability to identify business critical information has serious implications for the organisation. It also frustrates the ability to backup systems and migrate file systems. In fact, many organisations actually migrate the entire file system, even where users have left, because of the fear of losing one or more potentially important files. The distributed nature of files across departments and different PCs also frustrates the ability to construct electronic manuals, which are now expected by many customers.	on PCs and servers • Backup issues – which files and where? • Migration issues – which files to keep • Difficult to locate information for production of e-manuals
13	**Information completeness and accuracy**	This issue concerns the completeness or accuracy of information managed by an organisation. This is generally internal information and in most cases arises because information has either been partially entered or an error occurred during transfer. This not only arises because of manual data transfer between systems but also at the original point of entry. To address this issue, one organisation is now employing what they call an information quality officer. In the context of the engineering SME the information quality officer ensures that information relating to a specific project is complete prior to the commitment of design efforts and production of tooling and change parts.	• Partially entered information • Errors during input or transfer
14	**Quality systems Implementation and operation**	This class of issue relates to implementation and the resources required to operate a quality system. In addition, the large amounts of information that are produced as a result of achieving and maintaining ISO 9000/2 certification was also cited as a significant barrier and contributor to issues concerning information storage.	implement systems • Large amounts of information produced as a result of achieving and maintaining certification
15	**duplication Information**	Issues concerning information duplication involve multiple instances of information, which frequently arise as a result of manual data entry. Furthermore, where manual processes are implemented there is often a delay which impacts on information currency. In all cited issues an additional instance of information was being held within the MRP system. This can be a particular problem with Bills Of Materials (BOMs) for products which are largely bespoke and frequently commissioned at the customers' premises. If separate instances of the BOM exist it can be difficult to determine which is current given that small changes are frequently made by machinery manufacturers made during commission.	• Multiple instances impact on currency • Frequently hold additional instances in MRP system – Multiple BOMs between PDM and MRP common
16	**Information currency**	Information currency concerns the fact that design changes, spares and machine alterations are not automatically updated in other information systems (product configurators Bills Of Materials). This means that up-to-date builds are difficult to identify which has implications not only for sales but also spare parts and maintenance. This class of issue also concerns the widespread utilisation of manual timesheets to record activities of employees. This not only results in a considerable financial overhead but also frustrates the ability to accurately cost projects and monitor their progress in real or pseudo real-time	• Old information on product range, revisions and options • Out of date Bills Of Materials
17	**Paper based systems**	This class of issue concerns the fact that paper systems are still widely used to provide a master record of either drawings or part numbers. In many cases organisations had returned to a paper based system after experiencing problems with their computer based systems. This class of issue may therefore be considered to be related to information systems t functionality (or lack of).	• Use of Master Records for drawings, parts, inventory and machine numbers
18	**Information systems strategy and planning**	This class of issue concerns the decision making process and corresponding information systems planning. In each cited case there was a feeling that the strategy had, and is still, largely driven by accounting requirements and those individuals ultimately responsible for the financial stewardship of the organisation. It was observed that few organisations appeared to have a formal long-term information systems strategy other than for specific departments. Although, the MRP system was frequently cited as the organisations long-term information systems strategy.	• Driven by : 1. Accounting 2. Directors responsible for the financial stewardship of the company

The classification of information management issues arguably provides an informed view of the scope of the issues currently facing engineering SMEs. Furthermore, a greater understanding and insight into the relative significance of these issues can be established by considering the number of specific issues within each generic issue. Figure 1 shows the relative spread of cited issues over the generic issues and highlights the nine most prevalent or important issues. In particular, the figure highlights the significance of information exchange; manual systems and data entry; monitoring, control and costing; information flow from customers; IS functionality and information storage. These six generic issues represent over half of the total cited issues and as such provide an indication of the important areas or issues that need to be addressed.

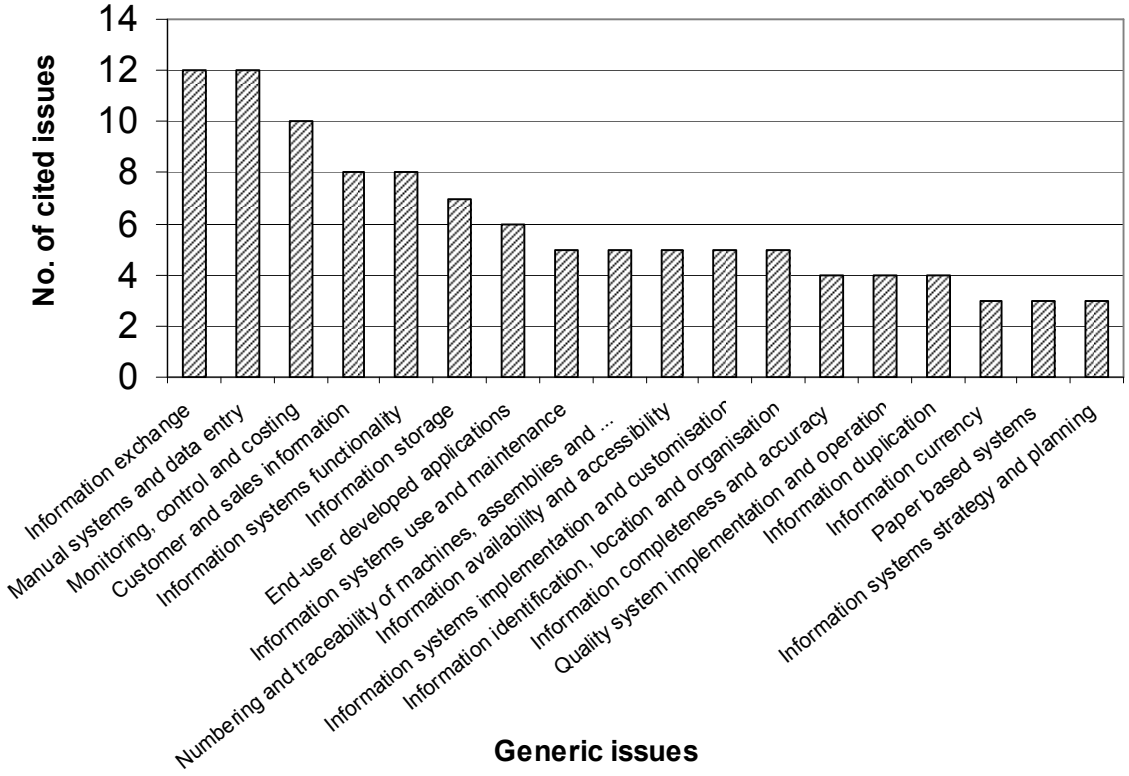

Figure 1. Spread of cited issues across the generic issues

4 DEPENDENCY AND CAUSALITY

In reality not all of the eighteen issues previously characterised are independent; rather they are related to at least one other issue. In order to provide a more complete understanding of these relationships, the dependencies and causalities have been further explored. This involved identifying those issues which are dependent upon, or may be considered to be significantly influenced by, other issues. For the purpose of this work, only significant dependencies and causalities have been highlighted. These are dependencies which are either self evident or represented by one or more related specific issues. In the latter case the 109 issues were re-evaluated to consider cause and possible effect.

The evaluation of dependencies and causalities reveals a set of fundamental issues which are either independent or are the primary cause of other issues. This superset of issues is particularly important and can be considered to represent the key barriers to improving information management. The set of 9 fundamental issues are summarised in the following sections.

4.1 Information exchange
Information exchange and in particular, the automatic exchange of information between computer based information systems, is one of the most widely cited and significant issues. The inability to automatically exchange information frequently results in the need for manual intervention which in turn has implications for information completeness and accuracy, affects information currency, and results in information duplication. As a results of this, almost one third of the total issues cited may be related to, or arise from, the fundamental issue of information exchange.

4.2 Information systems implementation and customization
Implementation and customization of information systems and in particular the completeness and effectiveness of the implementation, ultimately has a significant impact on the functionality, use and maintenance. A deficit in functionality, poor training and lack of acceptance of an implementation all contribute to the use of paper based systems over the computer based alternatives and the increasingly widespread use of end-user developed applications. The large number of dependent issues within this class highlights this as one of the top fundamental issues representing almost one quarter of total cited issues.

4.3 Monitoring, control and costing
Monitoring, control and costing is an independent issue which is not in itself significantly related to any of the other core issues. This may well be due to the fact that many of the individual issues highlighted in the study arise because of the current inability of many organisations to automatically monitor production and associated processes. This is frequently because the infrastructure necessary to undertake this has yet to be acquired and implemented. Notwithstanding this, monitoring, control and costing is the third most widely cited fundamental issue.

4.4 Information flow from customers and sales
Information flow from customers and sales is particularly important for manufacturing organisations. If only because this information is a prerequisite for effectively undertaking the design and manufacturing processes. As a consequence, it significantly impacts upon information completeness and accuracy of information held within many information systems within the organisation. In total, information flow issues can be considered to characterize almost 10 percent of total cited issues.

4.5 Information identification, location and organisation
Information identification, location and organisation and the inability to effectively undertake these activities has a significant impact upon information storage. In general, large amounts of duplicate and unnecessary information are stored which is costly both in terms of physical storage and also the time necessary for employees to navigate through large amounts of information.

4.6 Quality systems implementation and operation
Implementation and operation of quality systems also impacts on information storage requiring many organisations to maintain large amounts of information which in many cases may not add value. This may because the information itself is of limited potential value or mechanisms are not in place where value may be generated from the information.

4.7 Numbering and traceability of machines, assemblies and parts
Numbering and traceability of machines, assemblies and parts is, within the context of this study, largely independent of any other issue and, as a consequence, may be considered a fundamental issue.

4.8 Information availability and accessibility
Information availability and accessibility is also considered to be independent from all other generic issues and is hence also identified as a fundamental issue.

4.9 Information systems strategy and planning
Information systems strategy and planning represents only three percent of cited issues. Ironically, whilst it is difficult to explicitly relate this issue to other generic issues it is perhaps as a result of poor strategy and planning that many of the other fundamental issues arise.

4.10 Discussion

The fundamental issues and the aggregated percentage of total cited issues they represent are shown in Table 2. This shows that automated information exchange and information system implementation and customisation represent the greatest proportion of total cited issues (55%) and over 30% and 24% respectively. This supports the findings of section 3 which identify information systems and related issues as the major contributor of information management issues in engineering SMEs. The next three most prevalent issues; monitoring control and costing, information flow, and information identification, location and organisation represent 30% of the total cited issues and can be considered to be primarily related to information and overall management dimensions of information management. The remaining 20% of cited issues are associated with the issues of quality, traceability, information access and overall planning, which relate to all three dimensions of information management.

	Fundamental issue	**No. cited issues**	***Dependent issues***	**No. cited issues**	**Total cited issues**
1	**Automatic information exchange between computer based systems**	12	Manual systems and data entry	12	33
			Information completeness and accuracy	2	
			Information duplication	4	
			Information currency	3	
2	**Implementation and customization of information systems**	5	Functionality of information systems	8	27
			Paper based systems	3	
			Bespoke office applications	6	
			Information systems use and maintenance	5	
3	**Monitoring, control and costing**	10	-	-	10
4	**Information flow from customers and sales**	8	Information completeness and accuracy	2	10
5	**Information identification, location and organisation**	5	Information storage	3.5	8.5
6	**Implementation and operation of quality systems**	4	Information storage	3.5	7.5
7	**Numbering and traceability of machines, assemblies and parts**	5	-	-	5
8	**Information availability and accessibility**	5	-	-	5
9	**Information systems strategy and planning**	3	-	-	3

Table 2 – Relative spread of cited issues over the nine fundamental issues

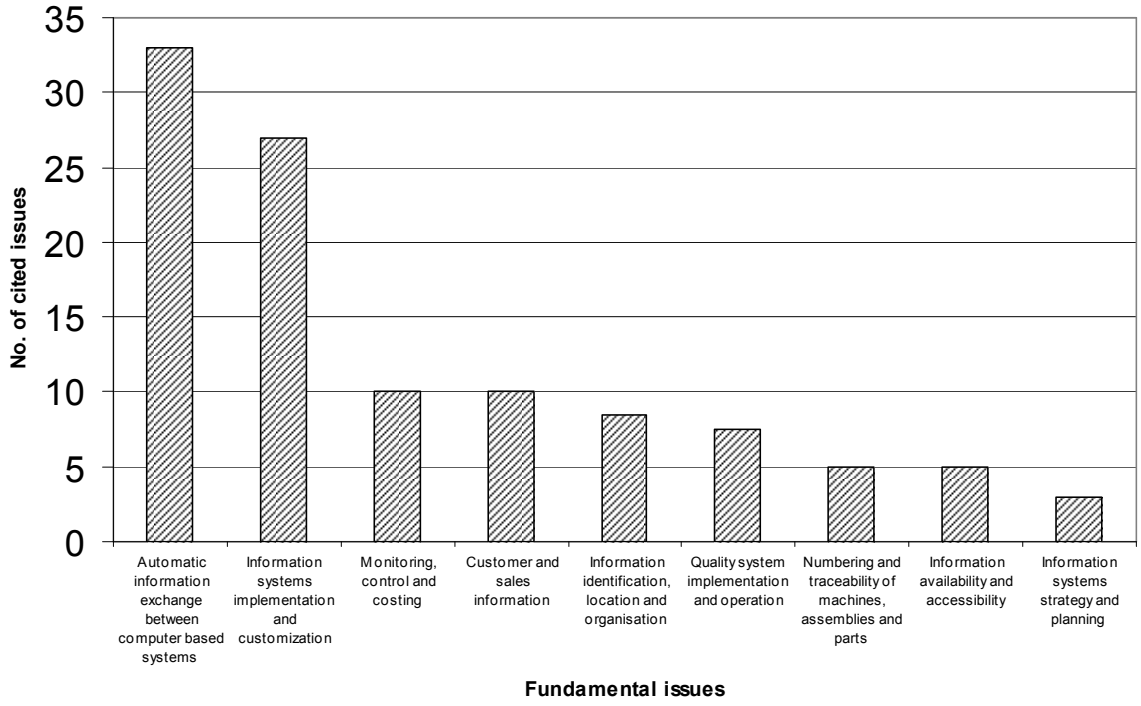

Figure 2. Spread of cited issues across the fundamental issues

5 THE BARRIERS TO IMPROVING INFORMATION MANAGEMENT IN ENGINEERING SMES

The scope of the information management issues established in this study reinforces the need to consider the information systems infrastructure as a whole. This includes all the various information systems and what can be thought of as their information interactions. In order to generate such understanding, engineering SMEs need to consider two key aspects; the intra- and extra-organisational flow of information and also the processes where information is generated, exchanged and accessed. These aspects may involve computer based tools and paper based systems, and a range of actors' including customers, suppliers and colleagues. The important elements that are relevant to this study are depicted in figure 3 and highlight information flow within the context of an engineering SME. In particular, the information flow between departments, customers, suppliers and other sites is depicted and the wide variety of information systems implemented and the large number of electronic files held on PCs and Servers are highlighted. This conceptual model of information flow provides the basis for mapping the barriers identified in this study and discussing their implications with respect to engineering SMEs. In order to aid the discussion the barriers are separated into intra- and extra-organisational, systems, planning and long-term considerations.

5.1 Intra-organisational considerations

There are two key intra-organisational considerations that concern the organisation and access of information. The first involves electronic files and the need to adopt either standard codes of practice for the naming and structuring of folders and files, or provide improved mechanisms for searching and retrieval of files across the corporate file systems (local machines and servers) e.g. document management systems. This both reduces time spent searching for information and improves the access. Examples include making service reports available to the design team and making detailed correspondence between engineering and customers available to sales personnel. The second intra-organisational consideration concerns the information generated by the service departments during interactions with customers. This information is arguably of significant value to sales and also the design department, and particularly for new product development, reliability and maintenance activities.

5.2 Systems considerations

The findings of this study highlight a particularly important systems factor that gives rise to many of the information management issues identified. This factor concerns the exchange of electronic information or the inability to exchange information. More specifically, there is a need for automatic information exchange to ensure that information across the organisation is up-to-date, accurate, complete and self-consistent. This involves technical issues regarding the physical communication of electronic information and importantly the need for a single unified accepted representation of information. This includes for example, document structures, file formats, codes and languages.

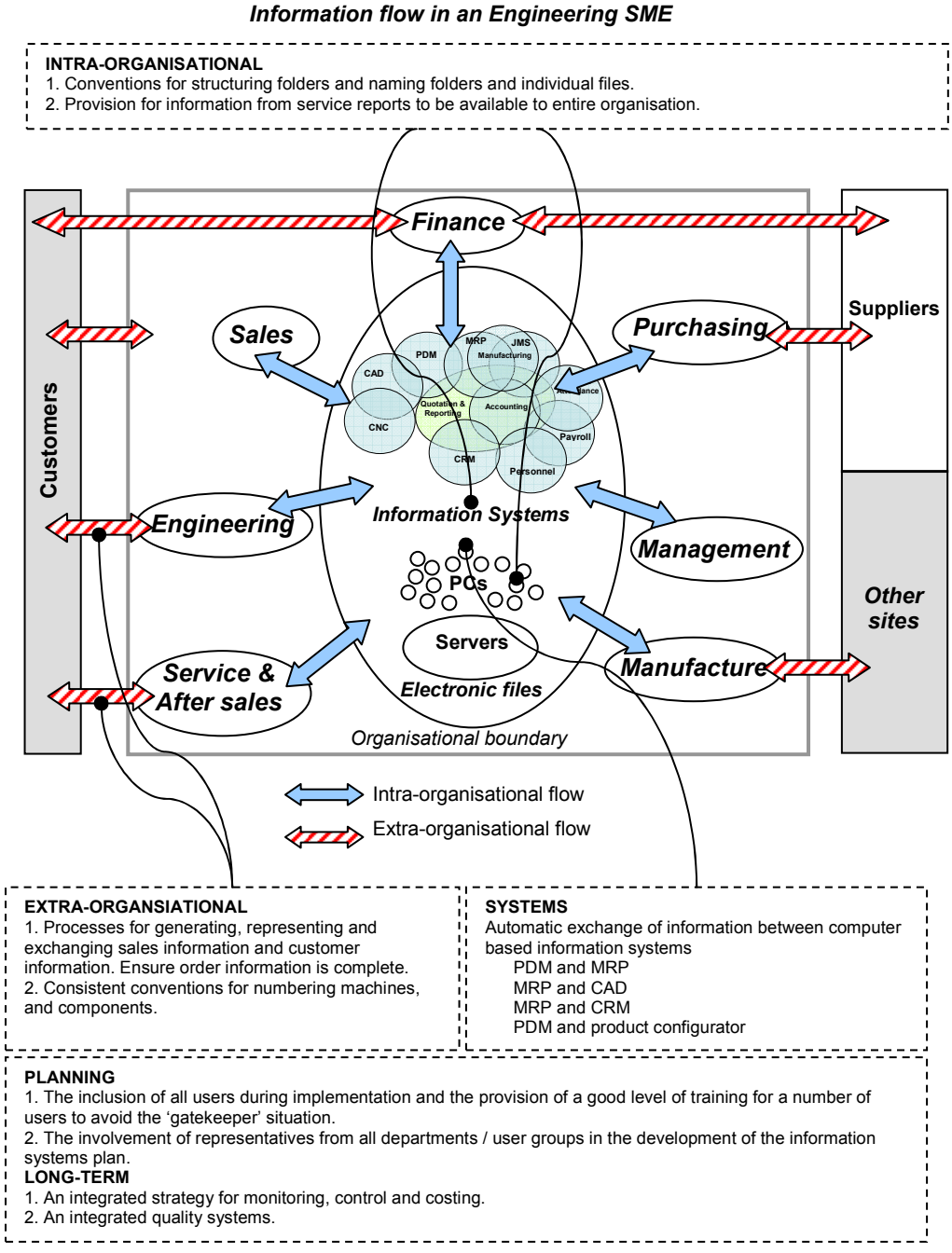

Figure 3. The barriers to improving information in an engineering SME

5.3 Extra-organisational considerations

From an extra-organisational perspective one of the key barriers to improving information management involves the numbering of parts and Bills Of Materials. More specifically, organisations need to agree corporate wide standards for naming systems, sub-systems and components, and their associated CAD files to enable part information and BOMs to be exchanged across the supply chain.

The second extra-organisational issue concerns the formalisation of processes for generating, representing and exchanging sales information with customers and also managing customer information within the organisation. It is critical that during the early stages of design accurate and complete information is available to the entire organisation. This is necessary for the design team and also the effective planning and commitment of resources.

5.4 Planning

The findings of the study reinforces the need for a more formal approach to information systems planning within engineering SMEs, and in particular, the need to involve representatives from the design, manufacturing, accounting, sales and purchasing departments, rather than a single individual or department as has frequently been the case in the past. Furthermore, there is also a need to involve all users of a given system in the implementation and training processes, particularly where new systems are implemented.

5.5 Long-term considerations

It is arguable that the study highlights two important long-term considerations for SMEs. These are quality systems and real-time monitoring, control and costing. In the case of quality systems, it is critical that they are fully integrated and implemented as part of the core business processes, rather than a parallel system. Where real-time monitoring, control and costing are considered, the critical barrier is a lack of capability and in particular hardware and software. Up until recently, the desire for real-time monitoring, control and costing has been driven by organisational requirements, however, as a result of pressures for organisations to be responsive and integrated within supply chains, real-time monitoring is likely to become a necessity. For these reasons, engineering organisations should begin to consider the introduction of additional elements for monitoring and control of design, manufacture, production activities and personnel.

6 CONCLUSIONS

This paper discusses the critical role of information in the operation and successful management of engineering organisations, and the need to develop more effective strategies for information management within the important and relatively neglected sector of the small to medium-sized engineering enterprises. It also argues the need for detailed empirical research of the information management issues in order to identify the fundamental barriers to improving information management within this class of organisation. To address these issues ten engineering SMEs operating in the Advanced Engineering sector in the UK have been studied in some detail revealing 109 issues relating to information management. From these issues a set of eighteen generic issues have been elaborated and characterised, which represent the scope of information related issues currently facing this class of organisation. In order to gain further insight into the relative significance of the generic issues the 109 cited issues have been classified with respect to the general classes. This reveals that over half of the 109 issues may be represented by only six of the generic issues: information exchange; manual systems and data entry; monitoring, control and costing; information flow from customers; IS functionality and information storage.

It is further argued that in practice the generic issues are not independent of one another and are frequently related to at least one other issue. A further stage of analysis is therefore undertaken to explore these dependencies and causalities. This process reveals a set of nine fundamental issues which arguably represent the key barriers to improving information management within small to medium-sized engineering organisations. These barriers and their implications for improving information management within engineering SMEs are discussed and a variety of intra- and extra-organisational, systems and long-term considerations are outlined.

The findings of this study and the understanding gained are not only critical for improving information management but also for the development and planning of an effective information systems strategy within this class of organisation. Furthermore, the findings also identify important issues for future research and suggest a range of organisational requirements which support the specification of additional or replacement elements of the information systems infrastructure.

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REFERENCES

[1] Curtis, G. and Cobham, D. *Business Information Systems: Analysis, Design and Practice*, Fourth Edition, Addison-Wesley Publishing Company, 2000, ISBN 0273651307

[2] Laudon, K.C. and Laudon, J.P. *Management Information Systems: New Approaches to Organisation and Technology*, Prentice Hall, New Jersey US, 1996, ISBN 0138577234.

[3] EMC Corporation. Information Lifecycle Management for ERP: Improve Performance, Availability, and Compliance without Disruptive, Expensive Infrastructure Upgrades, November 2004, White Paper.

[4] Chaffey, D. & Wood, S. *Business Information Management, Improving Performance using Information Systems*, Addison-Wesley, 2004, ISBN 0273686550.

[5] Dietel, J.E. Improving Corporate Performance, *Information Management Journal*, April 2000.

[6] Moran, N. Knowledge is the key, whatever your sector, *The Financial Times Limited*, UK, 1999.

[7] Galliers, R.D., Leidner, D. E. and Baker, B. *Strategic Information Management: Challenges and strategies in managing information systems*, Second Edition, Butterworth-Heinemann, Oxford, UK, 1999, ISBN 075063875X.

[8] Earl, M. J. *Information Management: The Organisational Dimension*, Oxford University Press, Oxford, UK, 1998, ISBN 0198294522.

[9] Duhan, S., Levy, M. and Powell, P. Information systems strategies in knowledge based SMEs: the role of core competencies, European Journal of Information Systems, 10, pp. 25-40, 2001, ISSN 0960-085X

[10] Boston, O. *Technical Liaisons in Engineering Design Understanding By Modelling*, PhD Thesis, University of Bath, 1998, UK.

[11] Christian, A.D. and Seering, W.P. A Model of Information Exchange in the Design Process, *ASME Design Engineering*, 1995,Vol. 83 No. 2 pp. 323-328.

[12] Irani, Z. & Love, P.E.D. Information systems evaluation: past, present and future, *European Journal of Information Systems*, 2001, Vol. 10, 183-188.

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